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Course design of integrated circuits in electrical and electronic technology

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Abstract: In light of the current development status of the domestic integrated circuit industry, there is an urgent need for interdisciplinary talent. Electrical and electronic technology, as a fundamental course in vocational education, is closely related to the integrated circuit industry. To meet job demands and support the professional skill development of students, the curriculum system can be restructured. Based on the requirements for cultivating high-quality, high-level talent in vocational institutions, this paper discusses the restructured curriculum system from various aspects, including teaching content design, instructional strategies, specific implementation, integration of ideological elements into the curriculum, and innovative teaching reforms. This discussion serves as a reference for other related courses and aims to enhance students' overall capabilities comprehensively.

1. Introduction

Since the invention of integrated circuits in the 20th century, they have gradually become the core of the modern electronic information industry, being widely applied in various intelligent and information-based sectors such as communications, healthcare, automotive electronics, industrial intelligent control, and the Internet of Things. They play an extremely important role in the development of contemporary society. Following the ZTE incident, China's integrated circuit sector faced a "bottleneck" dilemma, which remained a focal point of attention both domestically and internationally. As a foundational course in vocational-technical education, "Electrical and Electronic Technology" is essential for cultivating talent in the field of integrated circuits. In this context, it is crucial to discuss how classroom instruction on integrated circuits should be conducted within the "Electrical and Electronic Technology" curriculum.

2. Current Situation and Research Significance

2.1 Current Situation

This course is divided into two parts: the electrical engineering section and the electronics section. The electronics part is further divided into analog electronic technology and digital electronic technology, with most content closely tied to the concept of integrated circuits. In traditional teaching, students typically learn about the functions and applications of various chips, but they often lack an understanding of what integrated circuits truly are, why they can implement multiple functionalities, and how they do so. The section on "integrated circuits" occupies one class hour in the course "Electrical and Electronic Technology." Upon reviewing multiple textbooks, I found that the content related to "integrated circuits" is not extensive and is often minimal; some textbooks even omit it entirely. On one hand, with the continuous development of integrated circuits today, the industry is making new breakthroughs, making it challenging for the teaching content to be updated immediately. Even when textbooks include information on integrated circuits, the content tends to be outdated. If teachers do not keep up with industry trends, they may lack understanding and can only teach from the textbook. On the other hand, some educators believe that the content of this section should not be taught to students in "Electrical and Electronic Technology," adhering to the teaching philosophy of "emphasizing practice over theory," and focusing on imparting practical electrical skills. However, as a foundational course for students in electrical engineering, it is essential to develop students' abilities comprehensively and lay a solid foundation for subsequent specialized courses. Given the current significant talent gap in the integrated circuit industry and considering the future career development of students, the content related to integrated circuits should be thoroughly integrated into the "Electrical and Electronic Technology" course. If this section is overlooked, students may experience confusion while studying the electronic technology module[1]. Through years of teaching experience, I have found that when instructing on analog and digital electronic technologies—especially regarding operational amplifiers, registers, encoders, flip-flops, counters, and other chips—students often struggle to understand how a small chip can perform various functions, which can lead to feelings of frustration and negativity during their learning process. In the teaching of "Electrical and Electronic Technology," the concepts can be relatively abstract and difficult to grasp. Therefore, educators should clearly explain foundational knowledge and progressively unravel complex concepts, optimizing the transfer of knowledge to students. Additionally, this course embodies both fundamental science and technological science, and teachers should leverage this duality. By incorporating cutting-edge technological developments into the curriculum, we can mitigate the monotony of the subject matter, stimulate students' proactive learning engagement, enrich classroom content, and enhance students' overall competencies.

2.2 Research Significance

Therefore, the curriculum should include topics such as the origins of integrated circuits, the current state of development both domestically and internationally, the significance and role of integrated circuits, as well as knowledge of the frontiers of future technology, to fill the gaps in students' knowledge frameworks. This will also help stimulate students' interest in learning, enhance their understanding of integrated circuits, and expand their cognitive abilities. As a foundational course in electrical engineering, it is essential not only to teach the fundamental concepts well but also to organically integrate ideological and political education into the classroom, fostering students' correct values. Integrated circuits undoubtedly serve as an excellent case study for ideological and political education, illustrated by events involving ZTE and Huawei, the "bottleneck" issue, and the countless scientists and entrepreneurs who have dedicated themselves to the advancement of our country's chip industry. These examples serve as valuable elements for ideological education, helping to strengthen students' patriotism and awareness of challenges, while motivating them to strive for excellence and study diligently.

3. Overall Teaching Design

In light of the teaching characteristics of vocational colleges, which primarily aim to cultivate skilled talents, most vocational institutions currently adhere to an integrated approach to vocational education that combines theoretical knowledge with practical skills. This method is designed to enhance students' logical thinking, innovative awareness, and hands-on abilities. However, there are various training models to implement this philosophy effectively. To better integrate the content of integrated circuits, a project-based teaching model can be adopted. Additionally, it is beneficial to incorporate mechanisms that promote collaboration between schools and enterprises, incentivize learning through competitions, and extend learning opportunities beyond the classroom. These strategies aim to develop the comprehensive abilities, job awareness, and practical skills of students in vocational colleges.

3.1 Instructional Content Design

The content of "Electrical and Electronic Technology" in vocational and technical education includes three modules: "Fundamentals of Circuit Analysis," "Analog Electronic Technology," and "Digital Electronic Technology." The latter two sections pertain to electronics and are fundamentally based on "Integrated Circuits." Based on the student's knowledge structure, learning characteristics, and abilities, the electronic course content can be modularized as follows: typical analog circuits composed of discrete components → commonly used analog circuits formed by analog integrated chips → commonly used digital circuits constructed from digital integrated chips → classic examples made up of integrated modules. Each section of content will be presented in a project format, leading to the following categorization of the teaching material:

Project One: Diode Rectifier Circuit and Level Selection Circuit. This project primarily introduces the characteristics of diodes as discrete components and their specific applications in the rectifier circuit and level selection circuit.

Project Two: Construction of Amplifier Circuits. This project focuses on the characteristics of transistors and the common-emitter amplifier circuits they form. Building on this foundation, students will master the analysis and construction of multi-stage amplifier circuits. An audio amplifier serves as the project vehicle, allowing students to intuitively experience the amplification effect of audio signals and understand the concept of amplification.

Project Three: Analysis of Integrated Operational Amplifiers. This project mainly covers the fundamental characteristics of integrated operational amplifiers and the analysis and application of several commonly used integrated operational amplifier circuits. Using an analog multiplier as the project vehicle, students will gain an understanding of the operations involved in operational amplifiers.

Project Four: The Application of Digital Logic Gate Circuit Chips. This section primarily introduces several commonly used logic gate circuits and typical combinational logic circuits. Using a voter as the project vehicle, encompasses various types of common chips, facilitating students' understanding of the relationships and usage methods between different chips.

Project Five: The Application of Flip-Flops. This section mainly covers several commonly used flip-flops: RS flip-flop, JK flip-flop, T flip-flop, D flip-flop, and counters. Utilizing counting and frequency division functions as the project vehicle, it aims to master the application of digital integrated chips.

Project Six: Common Integrated Circuit Modules. This section primarily introduces commonly used medium-scale and large-scale integrated circuits. Currently, the integration level of chips is very high, allowing many logic circuits to be integrated within a single chip, eliminating the need to connect multiple small chips. Using analog-to-digital converters, digital-to-analog converters, and general-purpose processors as project vehicles, it completes the knowledge system loop[2].

In the project's setup, the classification is primarily based on the complexity of circuit components, ranging from discrete components to integrated circuit modules. This also reflects the current advancements in integrated circuit technology, facilitating students' understanding of the content.

3.2 Teaching Approach

To integrate the content of "integrated circuits," I propose the following teaching approach for this lesson: First, simplify the explanation of integrated circuits by using the simplest examples of integrated circuits, gradually introducing more complex structures to reflect the progressive nature of knowledge and enhance students' understanding and analytical skills regarding circuits. Second, diversify the content related to integrated circuits by expanding the teaching material to incorporate various aspects, fostering students' innovative thinking in their field of study. Educators should not only focus on the current developments in integrated circuit technology but also possess foresight regarding future trends, staying attuned to cutting-edge dynamics to ensure that knowledge remains relevant to practical applications. Third, narrate the story of integrated circuits by weaving the history of their development throughout the lesson, illustrating the significant contributions of earlier scientists and the current state of integrated circuits in our country, thereby emphasizing a sense of national pride and cultivating students' values and perspectives on life.

3.3 Specific Implementation

When explaining the first part of analog electronic technology, I can introduce the concept of integrated circuits to the students. Components such as diodes and transistors are made from semiconductors. The topic of semiconductor doping is already addressed in the section on diodes, which leads to discussions on electron diffusion and hole drift movements. This presents a significant distinction from the movement of electrons within conductors that generate current. Therefore, it is essential to introduce the concept of integrated circuits at the beginning of the course to lay a solid foundation for the subsequent lessons. For instance, I will outline the specific implementation process at the start of the course.

The lesson begins with the playback of the theme song from Huawei's press conference to engage the students emotionally. The Huawei event has profoundly touched everyone, and this theme song will resonate deeply with the students, setting the stage for the class. I will then ask the students why chips are so important and in which areas of daily life they are used. The students will respond with examples such as electronic devices like smartphones, computers, wearable technology, smart homes, and drones. Based on their answers, I will explain the concept of integrated circuits in detail. An integrated circuit is a miniature electronic device or component. It involves a specific manufacturing process that interconnects the necessary elements such as transistors, resistors, capacitors, and inductors within a circuit, fabricating them onto a small piece or several pieces of semiconductor wafers or dielectric substrates, and then encapsulating them within a housing to create a microstructure with the desired circuit functionality.

Guide students to distinguish between functional circuit boards formed through soldering and soldered circuit boards that can be used to build circuits by connecting various discrete electronic components such as resistors and capacitors. In contrast, integrated circuits are created by integrating many different circuit components onto a small chip using microfabrication technology. The world's first integrated circuit was introduced in 1958 when Jack Kilby connected five components—resistors, capacitors, and transistors—on a piece of semiconductor material, marking the rapid development of integrated circuits. To better illustrate the progression of integrated circuits in line with Moore's Law, I will ask students how many components are currently found in the integrated circuits of modern smartphones. This question aims to spark their curiosity and desire for exploration while showcasing the remarkable advancements and achievements in today's integrated circuits.

Using a simple transistor structure, I will introduce the manufacturing process of integrated circuits and compare it with modern integrated circuits. Here, I can vividly liken a single component to a house; when many components are integrated, it resembles a city, where each component has its role, collectively ensuring the smooth operation of the entire city[3].

3.4 Ideological and Political Elements in the Curriculum

In the implementation process, it is essential not only to focus on students' understanding of knowledge but also to integrate ideological and political elements, achieving the goals of knowledge transmission, skill development, and value shaping. As previously mentioned, the development of integrated circuits should serve as the main thread to structure knowledge. In this process, we can delve into the rich resources of ideological and political education by starting from the history of integrated circuits, the current state of the industry, and the patriotic stories of scientists. This approach will not overshadow the main content but will subtly enhance the educational experience.

When discussing the history of integrated circuits, we can share the story of Lin Lanying, the "mother of semiconductors" in China, who overcame numerous challenges to serve her country, as well as the tale of Wang Shouwu, a pioneer in semiconductor research in China, who lived a life of modesty and patriotism. These narratives can inspire students' patriotic sentiments and invigorate their fighting spirit.

When discussing the differences in integrated circuits between domestic and international contexts, I can recount the details of the "ZTE incident" that occurred in our country, compare our nation with the top ten global integrated circuit design companies, and highlight the existing gaps. This serves as a reminder to my classmates that only by daring to innovate and strengthening our capabilities can we establish ourselves amidst the tide of global change. By emphasizing that a strong nation is built on technological advancement, I aim to awaken students' awareness of potential challenges and instill a sense of mission to strive for our country's progress[4].

When talking about the current situation of the integrated circuit industry, we can talk about the scientific research achievements and entrepreneurial deeds of many companies and entrepreneurs, such as the achievements of the "Starlight China Core" project and the deeds of Academician Deng Zhonghan's team, to enhance the students' great craftsmanship spirit of striving for excellence, innovation and the pursuit of excellence, as well as the team's sense of teamwork.

The "integrated circuit" is undoubtedly a good resource bank of political thinking elements, which can be mined in depth from a multidimensional perspective, thus solving the problem of rigidity and scarcity of political thinking elements in engineering courses.

3.5 Innovative reforms in teaching

3.5.1 Establish an industry-teaching fusion mechanism and integrate teaching resources

Schools should cooperate with enterprises and research institutions to share resources, on the one hand, to help students understand the employment needs of enterprises and the current development of the industry, and to stimulate students' enthusiasm for learning[5]. On the other hand, there are many experienced engineers and technicians in enterprises or research institutions, who can be hired as part-time teachers to assist in the construction of the school, carry out lectures to share valuable cases of work practice, improve the practical application of students' ability and the ability to serve in the post, and realize the docking of the curriculum system with the actual industry.

3.5.2 Enriching the content of the second classroom

The second classroom is an extension and expansion of knowledge, which can be fully utilized to cultivate students' innovative and practical abilities[6]. The second classroom can ensure that students understand the knowledge in the first classroom based on the content of the competition related to the integration of the contents of the professional curriculum, and further over the theoretical content into practice, to enhance the overall quality of the students and innovation, and to broaden the path for future career development. For example, the National Vocational College Skills Competition IC development and application of the integrated circuit testing part of the competition requires students to follow the relevant circuit principles of circuit design, welding, and debugging, the second classroom can be sufficient for students to supplement the knowledge of the vacancy, and to promote the skills of students in all aspects of the enhancement.

4. Teaching Effects

This course design has already been implemented in the course of “Electrical and Electronic Technology”, and the effect is better after many times of teaching practice. Students are more receptive to the process of transitioning from discrete components to integrated chips, changing the shortcomings of the past. When the production process of integrated circuits is briefly introduced, most students show strong interest and take the initiative to collect relevant information and videos online, and some students learn through the video resources of previous years' vocational skills competitions, virtual simulation platforms, and microcourse libraries to improve their vocational skills.

5. Conclusions

After the overall restructuring of the curriculum, students have mastered multifaceted skills, which is a strong boost to the cultivation of high-quality, high-level, talented, and comprehensive professionals. The integration of IC into it to cultivate interdisciplinary and cross-field talents broadens the development path of students' positions and effectively improves the actual effect of teaching, which can be used as a reference for related courses.

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